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TECHNICAL REPORT

70-23-FL

EFFECTS OF A CONTROLLED ATMOSPHERE SYSTEM ON THE STORAGE LIFE OF LETTUCE

PART I: LABORATORY TESTS

by

Harold Gorfien
Abdul R. Rahman
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October 1969

UNITED STATES ARMY
NATICK LABORATORIES
Natick, Massachusetts 01760

Food Laboratory

FL-99

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TECHNICAL REPORT
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EFFECTS OF A CONTROLLED ATMOSPHERE SYSTEM ON THE STORAGE LIFE OF LETTUCE
PART I-LABORATORY TESTS

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Harold Gorfien
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Project reference:
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October 1969

Food Laboratory
U. S. ARMY NATICK LABORATORIES
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FOREWORD

As the result of complaints about the poor condition of lettuce arriving at military installations overseas, the U. S. Army Natick Laboratories investigated the TECTROL* system for transporting fresh fruits and vegetables in specially proportioned atmospheres in refrigerated containers.

This work was performed under Production Engineering, 2270.3. Mr. Harold Gorfien was the Principal Investigator.

The authors wish to acknowledge the assistance of the Transfresh Corporation, Salinas, California for providing the test TECTROL controlled atmosphere chests and the controlled atmosphere lettuce shipments from California to Boston, and of the following personnel of the U. S. Army Natick Laboratories: O. Stark, S. Bishov, R. Mansur, J. Breyer and K. Miller for assisting in gas analyses; and G. Taylor for his participation in gas analyses and product testing.

* TECTROL is a registered Trademark of Whirlpool Corporation.

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ABSTRACT

Laboratory tests were conducted to determine the effects on lettuce of TECTROL, a proprietary system for shipping fresh vegetables and fruits in specially proportioned atmospheres in refrigerated containers and railcars. Storage periods approximating the extended overseas shipping and distribution time frames of four to eight weeks required by the military were used. The tests showed that where controlled atmospheres were maintained, significant improvements in quality and storage life were obtained. Reductions in slime, pink rib and russet spotting were found. Increased storage life in air remained after removal from controlled atmosphere when compared with the quality of lettuce which had been stored in air by the conventional method.

EFFECTS OF A CONTROLLED ATMOSPHERE SYSTEM ON THE STORAGE LIFE ON LETTUCE
PART I-LABORATORY TESTS

Introduction

The Armed Forces are concerned with having the capability of providing good quality fresh fruits and vegetables in sufficient quantity to meet the requirements of military personnel. To supply the military overseas, extended shipping and storage periods are required compared to those for normal distribution to civilian markets in the continental United States. As a result, highly perishable produce will exhibit varying degrees of spoilage prior to arrival overseas. One of the items most difficult to supply is lettuce.

From July 1967 to April 1969, 56,680,156 lbs. of lettuce with a value of $7,648,906.00 was procured by DPSC for use by the various military services. This dollar value would be considerably increased if the cost of handling warehousing and shipping were included.

The problem of lettuce spoilage has existed for many years. Commercial improvements have been made in packaging, refrigeration, and shipping. Even though improvements have been made, reports continue concerning spoilage losses in lettuce on arrival overseas.

Literature Review

A great deal of research on lettuce storage life has been concerned with the short civilian market time requirement of one to two weeks from date of picking. Within recent years a relatively smaller amount of work has been conducted involving the longer overseas military time frame requirements of four to eight weeks.

The U.S. Naval Supply Research and Development Facility initiated research in 1953 on lettuce stored for the extended time periods required by the Navy for shipping and overseas consumption. Lettuce was packaged in a variety of films, and some test samples were treated with ethylene oxide gas to minimize microbial spoilage (1). As a result of these studies, the U.S. Department of Agriculture, under contract to the Navy, investigated the effect of temperature, trimming, carton liners, and various films for bagging individual lettuce heads (2, 3, 4). The best results with a series of 4 lettuce crops picked in 1958 and 1959 were obtained with specially trimmed polyethylene bagged lettuce heads in unlined crates. Average trimming losses after 3, 5, and 7 weeks at 33°F were 17.9%, 24.4%, and 47.2%, respectively. At 38°F after 3, 5, and 7 weeks, the average trimming losses were 29.7%, 46.6%, and 53.8%, respectively. The average number of decayed lettuce heads per box (24 lettuce heads packed in each box) at 33°F after 3, 5, and 7 weeks were 4, 7, and 14, respectively. The average number of decayed heads at 38°F after 3, 5, and 7 weeks were 5, 17, and 22, respectively. These studies showed that by proper trimming, packaging, and optimal (33°) storage temperature conditions, a reduction in lettuce spoilage would result. However, even at the best combination of trimming, packaging, and storage temperatures, considerable lettuce spoilage would result within the extended overseas military storage time requirements.

Navy shipboard field tests were conducted with a controlled atmosphere system produced and maintained by TECTROL* generators (5). These tests involved 3 crops of lettuce picked in January, March, and August 1965. The data indicated that the TECTROL generator system had the capability of maintaining lettuce with a significantly longer storage life. However, the TECTROL generator system was considered neither feasible nor practical for use aboard Navy reefer ships.

A test shipment of nitrogen packed lettuce sealed in polymylar bags was made to deployed submarines for evaluation in 1967 (6). However, nitrogen packing in polymylar was found to have an adverse effect on lettuce.

*TECTROL - a proprietary system of Whirlpool Corporation for shipping fresh fruits and vegetables through the introduction of specially proportioned atmospheres into existing refrigerated containers and railcars.

Included in the specification [7] developed by the U.S. Army Natick Laboratories for packaging and packing fresh fruits and vegetables is the allowance of a full telescope wax-impregnated box for lettuce. Field tests [8] were conducted by the Navy in 1969 involving a comparison of wax-impregnated fiberboard boxes with wooden crates for fresh produce. Based on data generated during the test, recommendations were made for shipping lettuce to the 6th Fleet overseas in wax-impregnated fiberboard boxes.

A laboratory study was made on the quality and respiration rate of lettuce held in low oxygen atmospheres for 7 days followed by 3 to 4 days in air [9]. The results showed that russet spotting was substantially reduced in a low oxygen atmosphere. Although the severity of pink rib was reduced in 1/2 percent O_2 at 50°F, paradoxically, it was intensified in 2% to 8% O_2 at 50°F. At 36°F or 41°F, none of the atmospheres affected the severity of pink rib.

At an NLABS meeting in 1967 of the Fruit and Vegetables Products Subcommittee of the National Academy of Sciences, a recommendation was made to determine whether the TECTROL-controlled atmosphere system would result in greater lettuce storage life [10].

Methods and Materials

After reviewing the available information and recommendations on the subject, it was decided to evaluate the TECTROL-controlled atmosphere system on a laboratory scale under well-controlled conditions for periods of time ranging from 5 to 7 weeks. This system involves the introduction of a properly proportioned blend of gases for specific fruits and vegetables into a container as soon after picking as possible. For lettuce, the gas composition consists primarily of nitrogen and low levels of oxygen and carbon monoxide.

For this test two different crops of Iceberg lettuce were used. The first crop was naked pack (unwrapped) lettuce picked 30 April 1968. The second crop was field-trimmed and wrapped lettuce picked 20 June 1968. All lettuce for each crop was grown in the same field under similar conditions. Boxes of lettuce which had been picked on the same day and in the same field were shipped in fully loaded mechanically 34°F refrigerated TECTROL rail cars from California to Boston. The TECTROL rail cars were opened at the Boston market 11 days after loading. At this point, the TECTROL-controlled atmosphere was replaced by air. The ten boxes were taken to NLABS and were randomally distributed between a laboratory size TECTROL chest, a control Transfresh chest of the same size and characteristics as the TECTROL chest, and a control large chill box both without controlled atmosphere. The TECTROL and control Transfresh chests operated at 38°F and 95% relative humidity. The control large chill box operated at 38°F and 85% relative humidity. Within 4 hours of opening the rail cars in Boston, nitrogen and carbon monoxide gases were used to produce a TECTROL-controlled atmosphere (primarily nitrogen with low levels of oxygen and carbon monoxide) at NLABS. Gas analyses were conducted on the TECTROL chest at 48-hour to 66-hour intervals throughout the storage period as required. A Fisher Gas Partitioner Model 25M was used to determine the percentages of the various gases present throughout the 24-day storage period. Air was added to the TECTROL chest as required at 48-hour to 66-hour intervals to maintain the oxygen level within a reasonable range. Oxygen ranged from 2% to 4% for most of the 35-day storage period reaching a minimum of 0.8% and a maximum of 6.6% for one day. Carbon monoxide was initiated at 4.8% and gradually reduced to 1.0% during the 35-day storage period. Nitrogen made up the difference. At the end of the 5-week storage period, the TECTROL chest was opened and the lettuce was evaluated and compared with the controls.

For the 2nd crop, 1/2 of the lettuce was transferred to the Control large chill box and evaluated 11 days later.

Evaluation of lettuce consisted of the following:

(a) Describing the general appearance of the entire box of lettuce (poor, fair, good, very good).

(b) Determining the edible yield for each individual lettuce head by the method described under reference (5).

(c) Describing the degree of spoilage (slime, pink rib, russet spotting) present using the terms trace, slight, moderate and great deal.

Data on edible yield were statistically evaluated by analysis of variance.

Results

The results with two different lettuce crops are presented in Tables 1, 2, and 3. These results show in terms of general appearance, edible yield, slime, and defects that at 36°F to 40°F lettuce stored under TECTROL-controlled atmosphere was significantly in better condition than lettuce stored in air. Furthermore, eleven days after removal from TECTROL controlled atmosphere, the lettuce was in better condition than lettuce stored continuously in air (Table 3). The data also indicates that the specific crop of lettuce stored for 5 weeks under TECTROL-controlled atmosphere plus 11 days in air (Table 3) was significantly in better condition than lettuce stored for 5 weeks in air (Table 2); for this comparison $P > 0.05$, least significant difference = 11.22. This laboratory evidence indicates the possibility that for extended shipping times TECTROL-controlled atmosphere has the capability of providing at least eleven days more shelf life over conventional container shipping.

The time period of five weeks under the TECTROL system is equivalent to anticipated shipping time overseas from California to either Vietnam or Europe. The time period of five weeks under TECTROL and eleven days in air is equivalent to the anticipated shipping time including an eleven day warehouse storage distribution period.

Table 1. Untrimmed Lettuce (picked April 30, 1968)-5 Weeks TECTROL-Controlled Atmosphere

Type Storage	General Appearance Open Box of Lettuce	Edible Lettuce Yield 5 Weeks After Picking Range (Percent)	Edible Lettuce Yield 5 Weeks After Picking Average (Percent)	Number of Lettuce Heads Examined	Number of Lettuce Heads Showing Internal* Defects Per Box Box 1**	Number of Lettuce Heads Showing Internal* Defects Per Box Box 2***
TECTROL Chest	Good	64-88	77****	47	0	2
Control TRANS-FRESH Chest	Fair-Good	62-85	72	47	10	11
Control Large Chill Box	Fair	22-86	68	47	13	11

* Defects after removal of 1 or 2 wrapper leaves. Primarily slime type defects with some russet spotting and pink rib.

** 23 Lettuce heads per box

*** 24 Lettuce heads per box

**** Statistical Interpretation. $P > 0.05$, Least Significant Difference = 4.03

Table 2. Field Trimmed and Wrapped Lettuce (picked June 20, 1968)-5 Weeks TECTROL Controlled Atmosphere

Type Storage	General Appearance Open Box of Lettuce	Edible Lettuce Yield 5 Weeks After Picking Range (Percent)	Edible Lettuce Yield 5 Weeks After Picking Average (Percent)	Number of Lettuce Heads Examined	Number of Heads Showing Slime Defect	Number of Heads Without Slime but Showing Other Defects	Total Number of Heads Showing Defects
TECTROL Chest	Very Good	38-94	78**	24	4	4	8
Control TRANS-FRESH Chest	Good	44-86	68	24	6	16	22*
Control Large Chill Box	Good	19-85	67	24	8	12	20*

* Defects/head and slime/head greater in controls than in lettuce stored under TECTROL.

** Statistical Interpretation. $P > 0.05$, Least Significant Difference = 6.09

Table 3. Field Trimmed and Wrapped Lettuce (picked June 20, 1968)-5 Weeks TECTROL-Controlled Atmosphere & 11 Days Air

Type Storage	General Appearance Open Box of Lettuce	Edible Lettuce Yield 5 Weeks After Picking Range (Percent)	Edible Lettuce Yield 5 Weeks After Picking Average (Percent)	Number of Lettuce Heads Examined	Number of Heads Showing Slime Defect	Number of Heads Without Slime but showing other Defects	Total Number of Heads Showing Defects
TECTROL Chest	Fair-Good	15-92	78**	24	7	4	11
Control TRANSFRESH Chest	Fair	4-78	53	24	22	1	23*
Control Large Chill Box	Fair-Poor	37-80	60	24	15	4	19*

* Defects/head and slime/head greater in controls than in lettuce stored under TECTROL.

** Statistical Interpretation. P>0.05, Least Significant Difference = 12.00

Conclusions

Evidence has been presented to demonstrate that under laboratory maintained TECTROL-controlled atmosphere, improvements in lettuce quality and storage life will result. Quality improvements involved (a) reductions in defects such as slime, russet spotting, and pink rib, and (b) greater edible yield. The 11-day increase in storage life occurred after removal from controlled atmosphere.

Improvements have been found under relatively ideal laboratory conditions. A field test has been conducted to determine whether the large available commercial TECTROL containers will give the results that were obtained in the laboratory. These results will be reported in a subsequent report.

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Laboratory tests were conducted to determine the effects on lettuce of TECTROL, a proprietary system for shipping fresh vegetables and fruits in specially proportioned atmospheres in refrigerated containers and rail cars. Storage periods approximating the extended overseas shipping and distribution time frames of four to eight weeks required by the military were used. The tests showed that where controlled atmospheres were maintained, significant improvements in quality and storage life were obtained. Reductions in slime, pink rib and russet spotting were found. Increased storage life in air remained after removal from controlled atmosphere when compared with the quality of lettuce which had been stored in air by the conventional method.

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